Sasakiconcha elegantissima new genus and new species (Gastropoda: Vetigastropoda: Anatomidae?) with disjointly coiled base

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ABSTRACT

Sasakiconcha elegantissima, a new genus and species from the Western Pacific is described. The specimens are most similar to members of Anatomidae (*Anatoma, Thieleella*) with a peripheral selenizone, but close the slit to a foramen, and lack a columella because of a disjointly coiled base resulting in an umbilical trough. Additionally, an aberrant specimen of *Scissurella morretesi* Montouchet, 1972, which shows repeated closure of the slit to form foramina, is discussed with respect to the evolutionary pathway from the ancestral open slit to its modification as a single or a series of foramina.

Additional Keywords: Protoconch, teratology, biodiversity, scanning electron micrographs, SEM

INTRODUCTION

The study of the scissurellid grade has revealed a significant number of new taxa over the last few years, from species to family-level (e.g., Marshall, 1993; 2002; Kase and Kano, 2002; Bandel, 1998; Geiger, 2003; 2006; Geiger and Jansen, 2004a, b). With these new taxa, more and more discrete shell types have been discovered. Shells with flat spires (*Satondella* Bandel, 1998; *Maxwellella* Bandel, 1998), the calyptraeiform *Depressizona* Geiger, 2003, and even the new slit-less forms such as *Trogloconcha* Kase and Kano, 2002, expanded on the more common trochiform shell morphologies.

Until recently, the above forms had been classified in Scissurellidae; however, recent molecular studies have shown that Scissurellidae is a grade (Geiger and Thacker, 2005). More specifically, Scissurellidae (*Scissurella, Sinezona, Satondella, Incisura*) and Anatomidae (*Anatoma, Thieleella*) do not form a clade, whereas other lineages (Sutilizoninae, Temnocinclinae, Depressizoninae) have yet to be included but are likely not to be part of either of the sequenced lineages (see Geiger and Thacker, 2005 for discussion).

The careful study of existing museum collections has been the main driving force behind these discoveries. Here, I report on some specimens found in the collection of the Muséum National d'Histoire Naturelle, Paris that exhibit yet another new shell morphology. Additionally, a note on an abnormal specimen of *Scissurella morretesi* Montouchet, 1972, shows that the transition from single slit to multiple foramina can occur even in modern species.

MATERIALS AND METHODS

Specimens were mounted on double-sided carbon tabs (Ted Pella, Redding, California), sputter-coated with gold in a Cressington 108 auto sputter coater with rotary-planetary stage, and viewed in a Zeiss EVO40 XVP (Zeiss, Cambridge, UK) scanning electron microscope. Specimens of the new species were cleaned with a wet artist brush and a tungsten needle; the specimens appeared to be too fragile to withstand ultrasonic cleaning.

The number of specimens is indicated by the number separated by a comma from the museum acronym (see below). Protoconch whorls are counted following Geiger (2003).

Institutional abbreviations used in the text are: AMS: Australian Museum Sydney, New South Wales, Australia; BMNH: The Natural History Museum, London, Great Britain; LACM: Natural History Museum of Los Angeles County, Los Angeles, California, USA; MNHN Muséum National d'Histoire Naturelle, Paris, France; NMNZ: Museum of New Zealand Te Papa Tongarewa, Wellington, New Zealand; UMUT: University Museum, University of Tokyo, Japan; USNM: United States National Museum, Smithsonian Institution, Washington, DC, USA.

SYSTEMATICS

Vetigastropoda Salvini-Plawen, 1980
? Anatomidae McLean, 1989.
Sasakiconcha new genus

Type species: *Sasakiconcha elegantissima* new species.

Differential Diagnosis: *Anatoma* and *Thieleella* share the position of the slit at the periphery, but the slit remains open, and the suture is always below the lower keel of the selenizone, even in the most depressed species, *A. paucispiralia* (Bandel, 1998).

Description: Shell depressed biconical, whorls rapidly increasing in size, no nacre. Protoconch sometimes partially covered by suture of subsequent whorl. Whorls not touching at base forming umbilical trough; no columella. Selenizone and foramen at periphery. Suture mostly at or above upper keel of selenizone of previous whorl. Umbilicus wide. Animal unknown.

Etymology: *Sasaki–*: honoring Takenori Sasaki of the University Museum of the University of Tokyo for his significant contributions to the systematics of basal gastropods. *–concha*: Latin for shell. Sasaki's shell. Gender feminine.

Remarks: *Sasakiconcha* is tentatively placed in Anatomidae because of the peripheral position of the selenizone. That position was shown to discriminate between major scissurellid/anatomid lineages in an exploratory phylogenetic analysis of shell characters (Geiger, 2003). The most likely alternative hypothesis is that *Sasakiconcha* represents yet another independent lineage of slit-bearing, small vetigastropods.

Many species of *Anatoma* show converging margins of the slit, but in no species do they fuse and enclose a foramen. *Sasakiconcha* is not based on senile specimens of *Anatoma*, as the foramen is found over a wide range of shell sizes (4–8 mm). Not a single specimen of *Anatoma* or *Thieleella* with a closed foramen is known.

Sasakiconcha must form its foramen by a different process compared to most *Sinezona* or *Sukashitrochus*. *Sasakiconcha* closes the foramen from fairly early growth onward, i.e., at about half-maximum size, in contrast to most scissurellids, which close the foramen at about 4/5 of maximum size. It implies that, with growth, the anterior margin of the foramen is resorbed, while shell material is added at the apertural margin, leaving a foramen of approximately constant proportion over a wide range of shell sizes (4–8 mm). In contrast, juveniles of *Sinezona* and *Sukashitrochus* have an open slit, which only closes once the animal is fully grown. Only *Sinezona globosa* Geiger, 2006, known from the two type specimens and USNM 500687 (Caribbean locality data most likely wrong), also closes the foramen in not fully grown specimens (Geiger, 2006). Comparison to other foramen-bearing small vetigastropod genera of the scissurellid grade (*Sutilizona*, *Temnocinclis*, *Temnozaga*, *Depressizona*) is not possible due to the scarcity of material.

The overgrowth of the selenizone by the shoulder of the subsequent whorl is unique among Recent Vetigastropoda, but is known from some fossil genera (Brookes-Knight et al., 1960): e.g., *Agniesella* Cossmann, 1909 (Portlockiellidae), *Umbotropis* Perner, 1903 (Gosseletinidae), and *Catachisma* Branson, 1909 (Gosseletinidae). The overall shell morphology is most similar to the caenogastropod genus *Cochliolepis* Stimpson, 1858 (Vitrinellidae), though this latter misses the selenizone indicative of a vetigastropod placement for *Sasakiconcha*. Sowerby (1820–1834) illustrated *Scissurella elatior* Sowerby, 1831, on an unnumbered plate with the selenizone overgrown by the subsequent whorl. This character is not discussed as the species was introduced as a *nomen et figura*, without indication of where it was found. Sowerby (1842, 1852) placed it as a Recent species occurring off the coast of Britain, from where only *Anatoma crispata* (Fleming, 1828) is known. It is thus most likely that Sowerby's (1820–1834) figure was stylized and is erroneous with respect to the overgrowth of the selenizone. The whereabouts of the type material of Sowerby's species is unknown.

Sasakiconcha elegantissima new species
(Figures 1–2)

Differential Diagnosis: The cited generic characters will readily identify *S. elegantissima*. The most similar species is *Anatoma paucispiralia* (Bandel, 1998) described from Satonda, Indonesia. Shared characters include the overall biconical depressed shell shape, the protoconch lacking an apertural varix, and the short teleoconch I. The protoconch is half the size in *A. paucispiralia* (150 µm vs. 325 µm), teleoconch I is longer in *A. paucispiralia* (0.125 whorls vs. 0.05), the suture is below the lower keel of the selenizone of the previous whorl (i.e., the selenizone is not obscured), the sculpture of the shoulder has distinct axial and spiral components, the base has reticulate sculpture, and the slit is open although the aperture of the illustrated holotype (Bandel, 1998: pl. 14, figs. 2–4) is slightly chipped.

Description: Shell biconical-depressed, *Sinum*-shaped, to 8.5 mm (holotype); thin, fragile. Protoconch 285–325 µm (mean = 311 µm, n = 4, 325 µm in holotype), 0.75 whorls, flocculant sculpture (mostly eroded in holotype), no apertural varix, apertural margin convex; sometimes partially covered by suture of subsequent whorl. Teleoconch I <0.05 whorls. Teleoconch II up to 1.75 rapidly expanding whorls. Shoulder slightly convex, early teleoconch II with axial cordlets only, interstices irregular with tiny pits; after 0.5 whorls, axial cordlets with approximately one dozen nodules, nodules becoming spirally elongated with strength of axial cordlets decreasing; after 1.25 whorls, sculpture transformed into approximately 50 spirally arranged, irregularly spaced, nodular cordlets; interstices with finest axial growth marks. Base with fine, stepped, longitudinally undulating, spirals, reaching just into uppermost portion of umbilical cavity, approximately 30 in 4 mm specimen, approximately 40 in 8 mm specimen. Umbilicus wide, walls steep, smooth; umbilical wall not connecting with previous whorl, forming spiral trough between umbilical wall and previous whorl produced by inner surface of shoulder. Selenizone at periphery, usually hidden by suture of

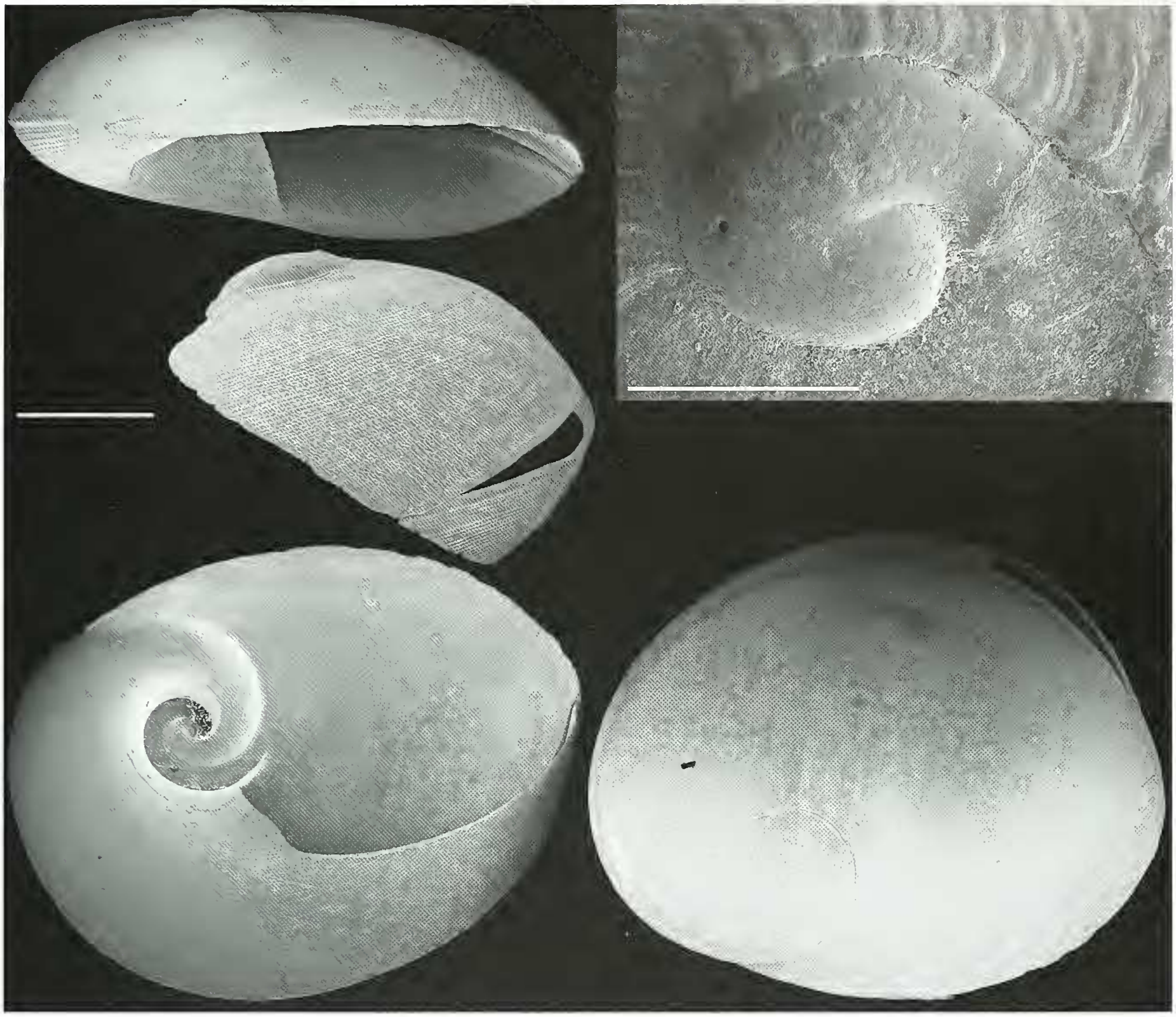

Figure 1. Holotype of *Sasakiconcha elegantissima* new genus and new species, MNHN type collection. Scale bar shell = 2 mm; scale bar protoconch = 200 µm.

subsequent whorl; slit closed anteriorly to form foramen, foramen formed in specimens ≥4 mm. In fully mature specimens (holotype), last 0.125 whorls descending. Aperture oblong, D-shaped, roof overhanging. Animal unknown.

Type Material: Holotype (MNHN type collection); paratypes: MNHN, 1 (Figure 2: left), 477–493 m, BORDAU1, DW1432, off Fiji, 17.333° S, 178.733° W; MNHN, 1 (Figure 2: middle), 300–302 m, BORDAU2, DW1523, Eua, Tonga, 21.300° S, 175.000° W; MNHN, 2 (one illustrated in Figure 2: right), 391–421 m, BORDAU2, DW1537, haut-fond, 21.683° S, 175.317° W; UMUT RM29213, 1; NMNZ M.273290, 1, 700–707 m, BORDAU1, DW1485, Fiji, 19.050°S, 178.500°W.

Type Locality: 970–983 m, BORDAU2, DW1531, Eua, Tonga, 21.200°S, 174.933°W.

Etymology: *Elegantissima:* elative of Latin adjective: extremely elegant referring to the overall aspect of the shell.

Other Material Examined: Fiji: MNHN, 1, 700–707 m, BORDAU1, DW1485, 19.050° S, 178.500° W; Tonga: MNHN, 1, 456–510 m, BORDAU2, DW1509, Tongatapu, 21.083° S, 175.367° W; MNHN, 2, 578 m, BORDAU2, DW1585, Vava'u group, 18.550° S, 173.950° W; French Polynesia: MNHN, 1, 600–620 m, BENTHAUS, DW1889, east of Rap, 27.613° S, 144.262° W.

Distribution: Western Pacific (17–27.5° S, 144–175° W), 300–981 m [all shells only].

Remarks: *Sasakiconcha* is not a morphological endpoint in a series of undescribed *Anatoma* species. The MNHN collection contains 23 undescribed *Anatoma* and

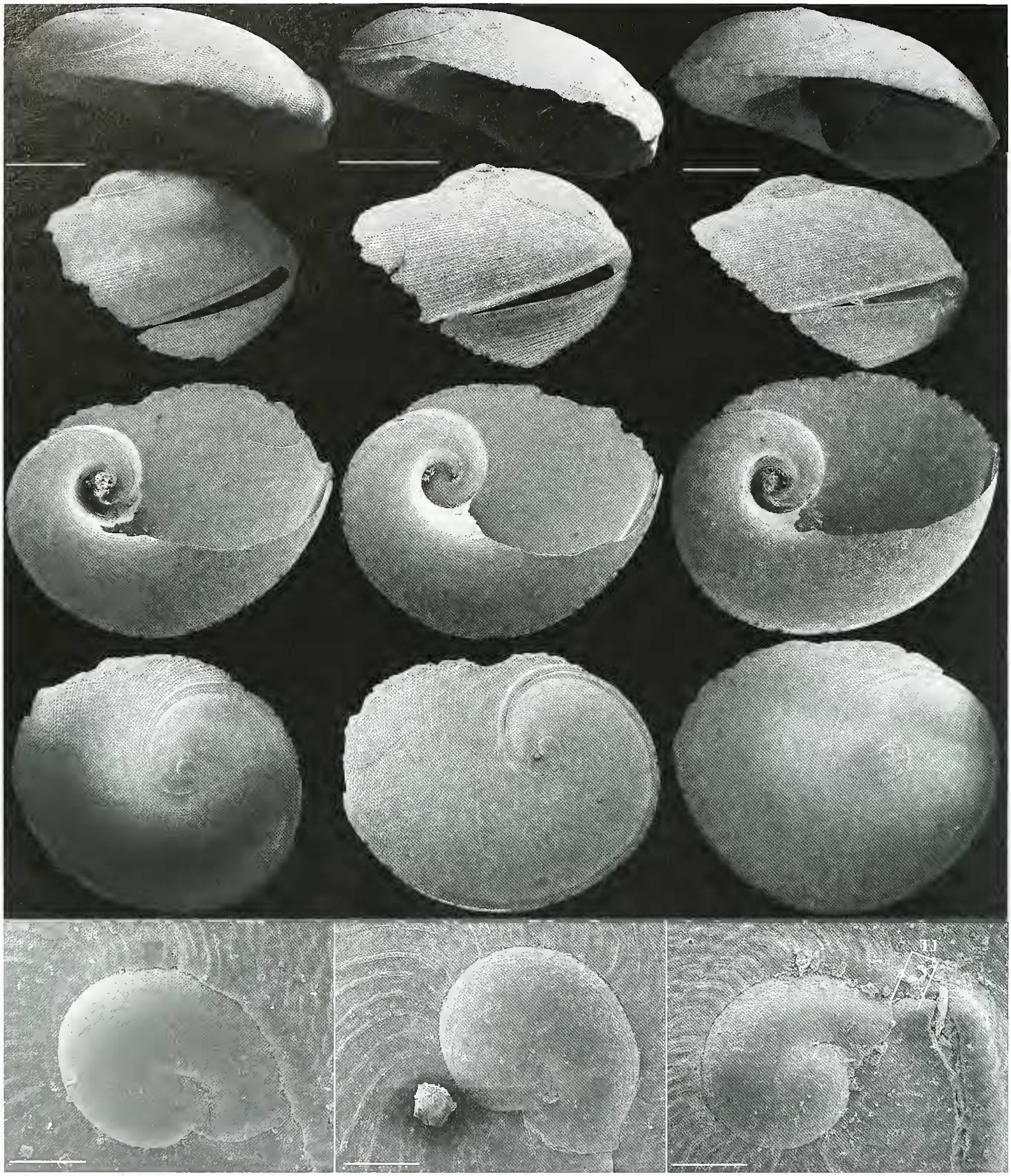

Figure 2. Paratypes of *Sasakiconcha elegantissima* new genus and new species. First row: apertural view; second row: lateral view showing closure of slit to foramen; third row: umbilical view; fourth row: apical view; fifth row: protoconchs. Left: MNHN, 1, 477–493 m, off Fiji, 17.333° S, 178.733° W; middle: MNHN, 1, 300–302 m, Eua, 21.300° S, 175.000° W; right: MNHN, 2, 391–421 m, haut-fond, 21.683°S, 175.317° W. Only in one of the smaller specimens on the left the slit is still open. In the other two, which are approximately half the size of the holotype, the slit is already closed to a foramen. Scale bars shells = 1 mm; scale bars protoconchs = 100 µm; T1: extent of teleoconch 1.

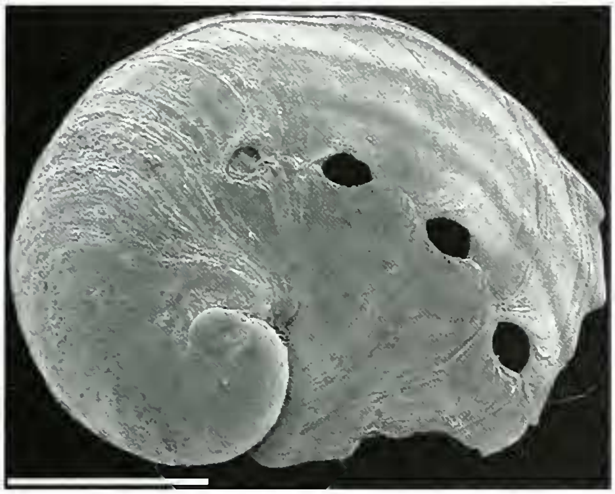

Figure 3. Juvenile *Haliotis rubra* Leach, 1814, from a hatchery. A short slit-less teleoconch I follows the protoconch. Teleoconch II immediately forms a series of foramina. Scale bar = 1 mm.

Thieleella species from the Indo-Pacific awaiting detailed study through electron microscopy. None of these even remotely approaches *Sasakiconcha*.

The umbilical trough is a character not known from any other scissurellid sensu lato or anatomid and is to my knowledge a novel configuration in gastropods; its function is unclear. Umbilical modifications have been shown to function as brood pouches in Larocheinae (Marshall, 1993).

Sasakiconcha elegantissima is a fairly large anatomid species, and one with a diameter of 8 mm does not even qualify as a micromollusk, which usually is defined as shells smaller than 5 mm. Despite its size, it is not the largest known anatomid. A specimen of *Anatoma euglypta* (Pelseneer, 1903) from Antarctica is 10.5 mm in diameter (Zelaya and Geiger, unpubl. data).

The protoconch of *Sasakiconcha elegantissima* is the largest known of any scissurellid/anatomid species by a factor of approximately two. It implies that rather large eggs are formed and that the number of eggs is relatively small, as has been observed in other scissurellids and anatomids [*Sinezona rimuloides* (Carpenter, 1865); *Anatoma euglypta*: Geiger, unpubl. data]. This is quite unlike the more familiar gonad condition in the large, broadcast spawning Vetigastropoda with millions of eggs (e.g., Bevelander, 1988). Large eggs themselves do, however, not entail brooding or parental care. Eggs may also be deposited onto any available hard substrate as shown for *Scissurella jucunda* Smith, 1890 by Strasoldo (1991).

REPEATED CLOSURE OF THE SELENIZONE

The selenizone with associated slit or foramen/foramina is typically found in Vetigastropoda, including Scissurellidae sensu lato (not in Larocheinae), Anatomidae, Pleurotomariidae, Fissurellidae, and Haliotidae, whereas in other families it is absent (Trochoidea, Lepetodrilidae, Peltospiridae, Neomphalidae). A sinus is formed in Seguenziidae, which had prompted Locard (1898) to include *Seguenzia* in Scissurellidae, whereas this latter genus is placed today in its own group besides Vetigastropoda.

That the open slit is the ancestral condition can be argued both based on data from the fossil record as well as from the ontogeny of Recent species. The open slit is found in the various pleurotomarioid families since the Paleozoic (Brookes-Knight et al., 1960; Harasewych, 2002), as well as in juveniles of *Sinezona* and *Sukashitrochus*, which eventually closes the slit to form a foramen at maturity (Geiger, 2003). Mature shells can be recognized by the distinct descending last quarter whorl of the adult shell. Haliotidae have modified the shell in a particular fashion in that they repeatedly open and close the slit to form a series of foramina (Delhaes, 1909). Most likely, the closure of the foramen lends more stability to the apertural margin of the shell. Similar shells of *Scissurella* with an open slit break more easily than those of *Sinezona* with a closed foramen. As Haliotidae usually live in high energy regions of the intertidal and shallow subtidal (Shepherd, 1973), a strengthening of the apertural margin throughout their life makes the repeated formation of foramina advantageous. The underlying mantle has a single, anteriorly open, slit, covering all open foramina (Crofts, 1929), while in foramen bearing Fissurellidae all stages from open mantle slit to fused mantle skirt can be observed (McLean and Geiger, 1998).

Intermediate forms are not widely known. Delhaes (1909) discussed the keyhole-shaped double foramen of the fossil pleurotomarioideans in the genera *Ditremaria* and *Phragmostoma*. Ontogenetically, Haliotidae immediately form a series of holes after a short slit-less teleoconch I (Bevelander, 1988: fig. 4.1; Sasaki, 1998: fig. 28; fig. 3), unlike in *Sinezona*, where the juvenile has an open slit, which is closed only once at maturity (Geiger, 2003).

A single specimen of an aberrant *Scissurella morretesi* is shown here (Figure 4). Two specimens of the species were available in conjunction with the original description of Montouchet (1972). As it is virtually impossible to legally obtain loans from Brazil at this time, no further material was available. No further exemplars of the species were found out of a total of 29,566 specimens examined (major collections include: AMS, BMNH, LACM, MNHN, NMNZ, USNM; many smaller collections not listed). Despite other abnormalities observed such as senile closure of foramen in *Scissurella* spp., the condition of the *S. morretesi* specimen discussed here is unique. The first SEM illustrations of the species are provided here.

As for all *Scissurella* species, usually the slit remains open throughout life. In the particular specimen, the slit was closed and re-opened three times successively. It does not appear to have been caused by damage to the shell; the shoulder and base of the shell in the vicinity of the closure show no growth irregularities. It rather seems

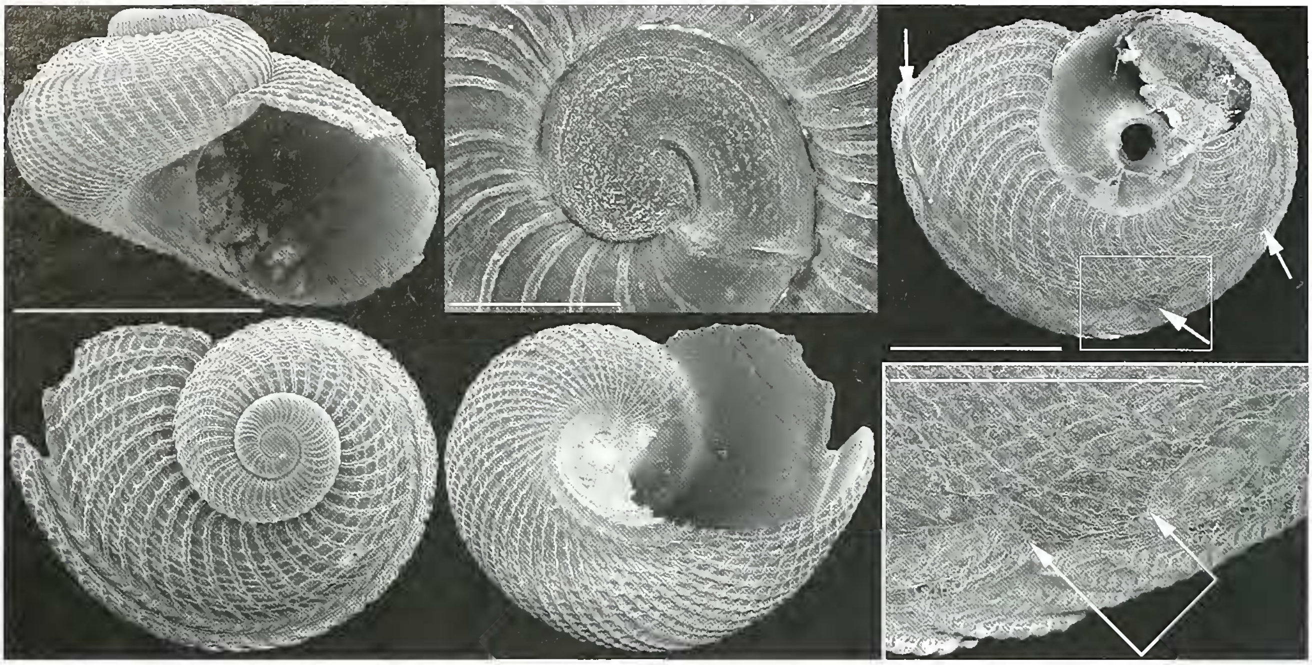

Figure 4. *Scissurella morretesi* Montouchet, 1972. Left: four views of normal specimen. Scale bar shell = 1 mm; scale bar protoconch = 100 µm. Right: apical view of aberrant specimen with evidence of three-fold successive closure of slit to foramen (bold arrows). Square shows portion of shell shown enlarged below; inset: Enlarged view of second closure; connected arrows show onset and end of closure; MNHN, 295 m, SE, Brazil, 18.983° S, 37.833° W. Scale bar shell = 1 mm; scale bar inset = 500 µm.

to have been caused by some sort of mutation/developmental abnormality. The specimen provides an illustration of a possible pathway from the ancestral open slit, to irregularly repeated closure of the slit, to patterned closure of the slit as seen in Haliotidae.

ACKNOWLEDGMENTS

This study was made possible by a Visiting Curatorship from MNHN, and NSF grant MRI 0402726 to Henry Chaney, Michael Caterino, and Daniel L. Geiger. I would like to thank all staff at MNHN for their hospitality and assistance during the stay. James McLean and Diego Zelaya offered constructive criticism that helped to improve the manuscript. Richard Petit provided details on the dating of some of Sowerby's works.

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